Are Two Laser Pulses (With Half Energy) Better Than One for Ion Acceleration?

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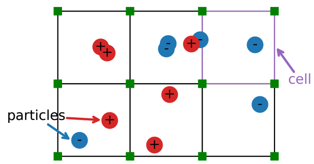
Motivation

- Accelerating Protons is important for a variety of applications
- Accelerator facilities are large and expensive
- In Ohio, there are 3 proton acceleration facilities for medical applications, 1 for scientific applications
- Laser ion acceleration could lead to much smaller, cheaper facilities
- Scarlet can get up to ~25 MeV, many applications need >100 MeV
- Peak Proton Energy scales with square root of laser intensity
- We were curious about a method described Ferri et al. 2019 in which two pulses of half energy yield better ion acceleration. We were curious to see how general this effect is.
- **How much can we increase proton energy without increasing the intensity?**

Background

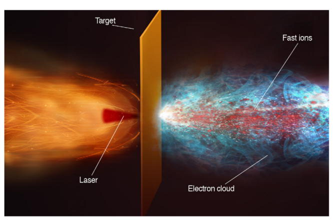
The Particle-In-Cell Technique (PIC)



- Fields are solved on a discretized grid, Maxwell's equations are solved by a set of difference equations.
- Particles are modeled by macroparticles which represent many ions or electrons.
- Particles are pushed by the fields on the grid, and the resulting fields are then calculated.

Target Normal Sheath Acceleration (TNSA)

- This is the method by which lasers are able to accelerate ions.
- Laser light interacts with electrons which absorbs some energy. These electrons then transfer some energy to heavier ions



Artistic Rendering of an ion acceleration experiment. Figure from [Macchi et al., Rev. Modern Physics, (2013)

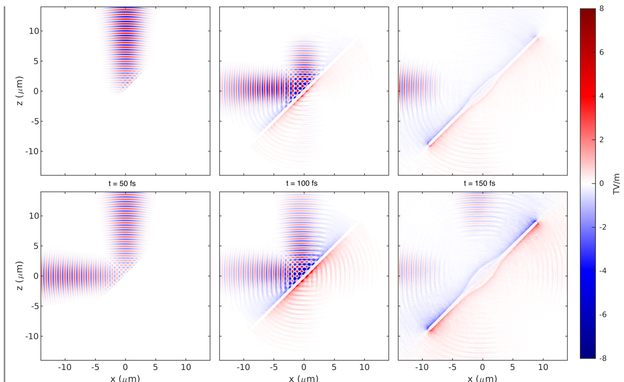
Methods

Set Up

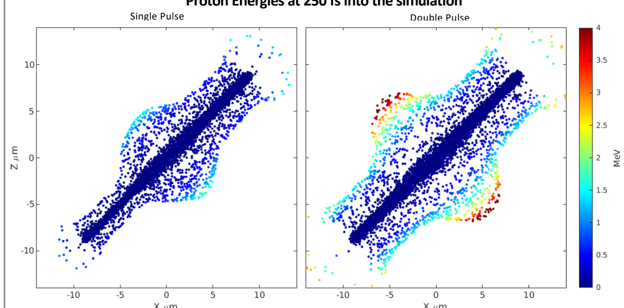
- We use a method similar to that described in Ferri et al. 2019 where two laser pulses of half energy irradiate a target at an angle and compare it to using one pulse at full energy.
- Ferri et al. 2019 found that an angle of incidence of 45˚ to normal yielded the highest energy ions
- We used the Large Scale Plasma (LSP) code, whereas Ferri et al. 2019 used EPOCH
- We ran our simulation to 1 ps with 20 as timesteps on a 14 by 14 μm grid and 2800 by 2800 cells

Results

Electric field component Normal to the Target



Proton Energies at 250 fs into the simulation



Laser Parameters

- Peak intensity of 5 x 10^{18} W*cm^{-2}
- Spot size of 1.86 μm (beam waist)
- Pulse width of 42 fs (FWHM)

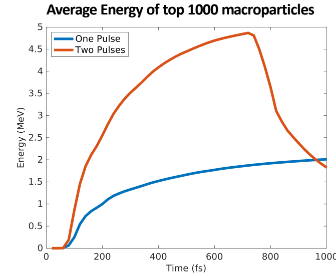
Target Parameters

- 0.46 μm Ethylene Glycol Target
- 36 particles per cell (9 particles per species for 4 species)
- No preplasma
- 1 eV starting temperature

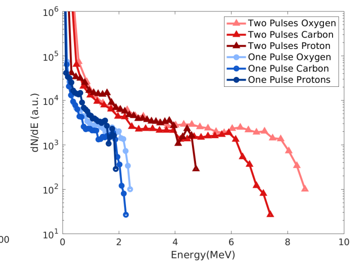
Analysis

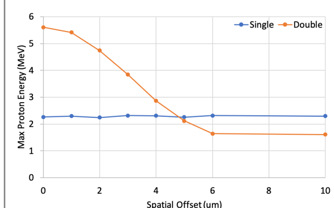
- We see an increase of 2.5x increase in the peak proton energies. This dramatic increase in energy is seen not only in the most energetic protons, but throughout the entire spectra.
- We see a faster increase in peak ion energy along with greater peak ion energy

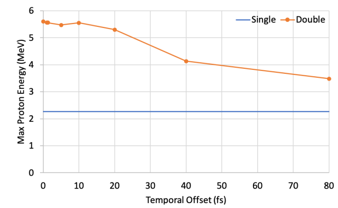
Average Energy of top 1000 macroparticles

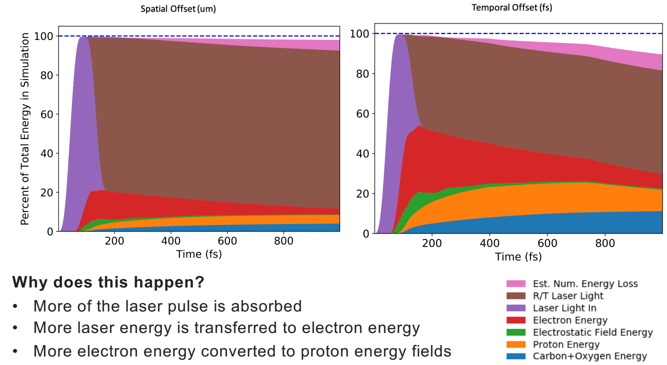


Proton Spectra at 450 fs









Why does this happen?

- More of the laser pulse is absorbed
- More laser energy is transferred to electron energy
- More electron energy converted to proton energy fields

Acknowledgements

- Simulations were performed on the ASC Unity cluster at Ohio State University.

BIBLIOGRAPHY

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